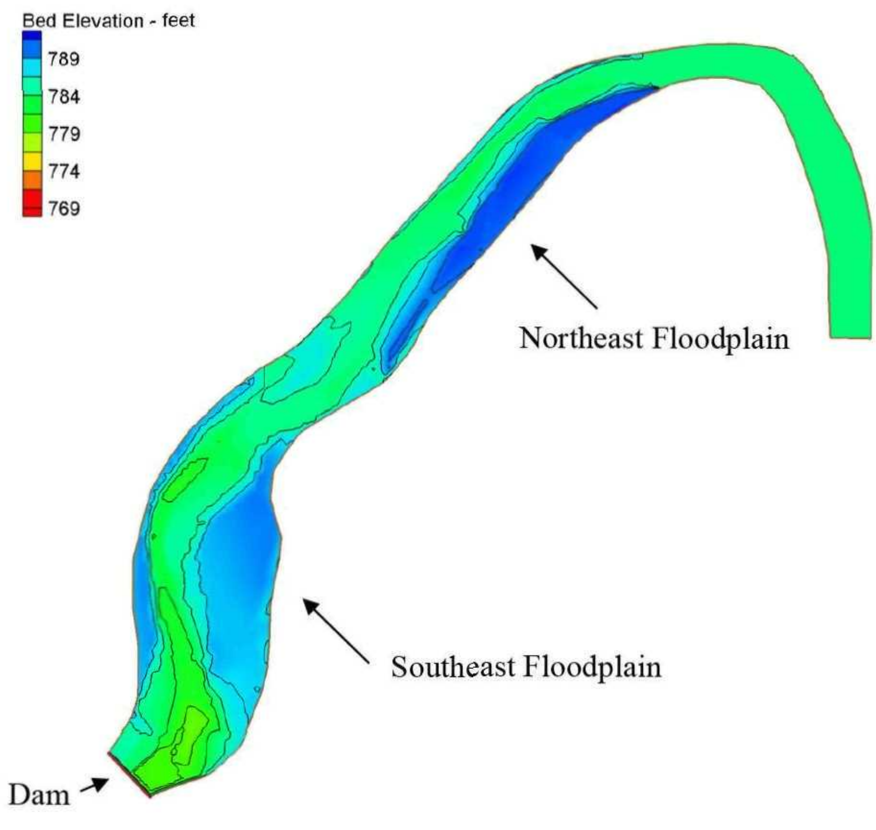
June 2012

Evaluation of Sediment Impacts from Removal of Easley Central Dam

Stephen H. Scott

Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199



Final Report

Prepared for EPA Region 4, Atlanta Georgia

INTRODUCTION

Up until the year 2010, the lower six miles of Twelve Mile Creek in Pickens Country, South Carolina contained three dams and reservoirs. Two of the dams, Woodside I and Woodside II were constructed in the early 20th century for hydropower, whereas the uppermost dam, Easley Central, was constructed as a water supply reservoir for Pickens Country.

From June 2010 to October 2011 the two lowermost dams, Woodside I (WSI) and Woodside II (WSII), were removed in an effort to restore the free flowing stream and associated habitat. The removal effort was performed by the Schlumberger Corporation as part of remediation requirements from the EPA Sangamo OU-2 superfund cleanup Record of Decision. The Sangamo superfund site is located in the Twelve Mile Creek watershed adjacent to the community of Easley South Carolina.

After the successful removal of the dams, the natural stream flow and sediment load was restored. Before removal, the reservoirs trapped the coarse sand sized sediments, with finer silt and clay sizes transporting to the lower reaches of the stream and subsequently into Lake Hartwell Reservoir. Periodic flushing of the reservoirs was performed to restore the reservoir storage capacity for hydropower operations.

Immediate improvements to the in-stream and stream side habitat were observed after dam removal. Stream bed pool and riffle sequences containing a coarse sediment substrate appeared in the stream reaches previously contained by the reservoir pools. Additionally, organic debris from streamside vegetation and fallen trees increased habitat diversity. In addition to improvements in stream ecology, recreational benefits have been realized. During moderate to high flows in Twelve Mile Creek, white water conditions occur due to the relatively steep bed slope. Flow velocities up to 10 feet per second occur along with large rocks and deep pools, creating ideal Kayaking conditions.

BACKGROUND

Before the hydropower dams were removed the sediment behind the dams was dredged to minimize the downstream sedimentation impacts. Just below the lowermost Woodside II hydropower dam site, a significant decrease in bed slope occurs due to the downstream Lake Hartwell backwater. Sediment transport model simulations indicated significant deposition of sands in the vicinity of Lay Bridge if the reservoir sediments were allowed to remain behind the dams. It is estimated that 500,000 cubic yards of sand would transport to the lower stream reaches below the WSII dam location.

Because of the benefits realized from the removal of the two lower hydropower dams, studies are underway to evaluate the feasibility of removing the uppermost Easley Central water supply dam. A comprehensive study was conducted to evaluate the impacts of removing the dam, including the volume of sediments behind the dam and in the floodplains, as well as the degree of existing PCB contamination (Kestrel Horizons 2011). Although the study provided the volume of sediment in the reservoir and floodplains behind the dams, it did not provide an estimate of post dam removal sediment transport and impacts to the bed below the dam if the sediments are allowed to remain behind the dam.

The study presented in this report will detail the potential transport of sediment from behind Easley Central dam after removal. Two numerical models were utilized to evaluate sediment transport from the reservoir. A two dimensional sediment transport model, AdH, was used to evaluate the spatial distribution of scour throughout the reservoir. This model was used to address the problem of how scour will proceed through the reservoir. A two dimensional model can address vertical incision through the reservoir bed as it adjusts. However, the processes that need to be addressed include both vertical incision and channel widening due to over-steepened banks and subsequent bank failures. The 2D model cannot address channel widening due to bank failures.

A one-dimensional model, HEC-6T, was utilized to evaluate scour volumes and subsequent downstream channel impacts. The scour path determined from the 2D model aided in the development of crossections in the one dimensional model for total scour and downstream transport calculations. The estimated base width of the erodible channel was estimated from the crossection data presented by Kestrel Horizons. An average bed elevation was then assigned to the crossection. A total of nineteen crossections defined the reservoir in the 1D model. The 1D model domain represented Twelve Mile Creek from a point 3000 feet above Easley Central Dam to the Lake Hartwell Reservoir backwater.

2D MODEL SIMULATION DESCRIPTION AND RESULTS

The goal of the 2D model study was to evaluate the spatial scour patterns in Easley Central reservoir after the dam is removed. These scour patterns guided the development of a 1D model for estimating total scour volumes from the reservoir and impact on the downstream bed.

The 2D model developed for this study contains 3700 nodes and 6900 elements (Figure 1). The model bathymetry was developed from the Kestrel Horizons bed surveys, with sediment depths determined from the difference in elevation of the bed surface sediment and the underlying bedrock. Two simulations were evaluated.

The first model simulation was for a steady-state two year return flood discharge (3000 cfs) in the creek, with the existing dam (dam elevation of 784 feet). The purpose of this simulation was to determine how the reservoir responds to high flow in terms of spatial distribution of erosion and deposition behind the dam. The velocity distribution in the reservoir is presented in Figure 2. Velocities range from approximately 3 – 6 feet per second, with little or no flow on the floodplains. The sediment transport impacts are seen in Figure 3. The upper reaches of the reservoir scour, with side channel deposition occurring. Sediments mobilized upstream deposit in the deeper downstream pool just behind the dam. This scour and deposition process during high flows tends to fill in the lower reservoir with sediment which decreases the reservoir water storage capacity, thus requiring periodic sediment sluicing through the dam to restore capacity.

To evaluate the spatial path of erosion through the reservoir sediments after dam removal, the model simulated lowering of the dam 12 feet (from 784 feet to 772 feet). A constant flow of

1000 cfs was utilized in the model during the simulation. The results are found in Figures 4 and 5. Note that the channel incision and subsequent scour follows the remnant channel thalweg behind the reservoir (Figure 5). Channel incision begins on the Eastern side of the dam where the deeper pool is maintained by sediment sluicing operations. The incision pattern follows the thalweg upstream, with the channel tracking the eastern side of the reservoir, away from the potentially contaminated southeast floodplain.

1D MODEL SIMULATION DESCRIPTION AND RESULTS

Crossections were developed in the 1D model based on the 2D model incision and scour pattern. Erodible base widths were estimated, ranging from 200 feet near the dam to approximately 100 feet or less in the uppermost crossections. Averaged bed sediment depths ranged from approximately 11 feet near the dam to 7 feet in upstream crossections.

Two modeling scenarios were simulated. The primary goal of the first simulation scenario was to remove the dam in four foot increments to minimize sedimentation impacts to the channel below the dam. Each removal scenario was subjected to a flow hydrograph consisting of 10 days at 500 cfs, followed by steady increases in flow up to 3000 cfs which remained steady for five days (Figure 6). This hydrograph was designed to scour the maximum sediment out of the reservoir for each incremental lowering of the dam. The sediment inflow into the reservoir was supplied by a sediment rating curve based based on the Toffaletti sediment transport capacity relation.

The second modeling scenario simulated a more practical dam removal scenario. It is more likely that the dam will be removed at a lower stream flow, thus the model was run at a constant steady 500 cfs for fifty days with the dam removed.

Scenario 1 – Staged Dam Removal Simulation

Five simulations were conducted under this scenario, with dam elevations of 784 feet (dam in place), 780 feet, 776 feet, 772 feet, and 768 feet. For each scenario, the total sediment released from the dam per scenario was computed, along with estimated downstream impacts. Figure 7 presents the Twelve Mile Creek bed elevation profile used in the model, with the extents ranging from 3000 feet above Easley Central dam (zero on the plot x-axis) to a point six miles downstream. Note that the location of Easley Central dam, the WSI and WSII locations, and Lay Bridge are noted on the plot. The model results are depicted as total sediment transport flux along the channel (Figures 8-12), and change in channel elevation before and after the simulations (Figures 13 and 14). The sediment flux along the channel is summarized in Table 1. As with Figure 7, pertinent locations are indicated on the plots.

For the sediment flux plots, the total sediment mass (tons) entering the system for each simulation occurs at zero on the x-axis of the plots (total sediment load entering the reservoir). The total sediment leaving the reservoir is the total flux indicated at the Easley Central dam location. Increases of total sediment flux downstream indicates scour (sediment added to the flow), with decreases of sediment flux past a point indicate deposition (sediment taken out of the flow). For the dam in place (Figure 8), the net sediment scoured from the reservoir is zero, with some deposition occurring between Easley Central and the WSII location, and scour occurring between WSII and Lay bridge, as well as downstream. For the remaining simulations, the reservoir scours, with varying degrees of deposition and scour occurring downstream. The second row of Table 2 summarizes the total sediment mass removed from the reservoir for each stage of removal. The total mass of sediment removed is 100,558 tons or 80,044 cubic yards. To convert mass to volume, multiply by 0.796.

The change in bed elevation is presented in Figures 13 and 14. Figure 13 and Table 1 indicate that the bulk of the sediment (98%) will pass below the WSII location, with only two percent of the sediment remaining in the channel. For all five simulations, a cumulative total of 312,409 tons of sediment (248,677 cubic yards) were passed through the system. This results in a deposition thickness of up to five feet occurring approximately 1000 – 1500 feet below lay bridge. However, the sediment scoured from the reservoir is only 32 percent of the total sediment passed downstream, with the bulk of it due to river inflow sediment load. Thus the contribution of the 80,000 cubic yards of sediment scoured from the reservoir would be approximately 2 feet of the maximum 5 foot deposit.

Scenario 2 – Dam Removal at a constant 500 cfs

A more realistic dam removal scenario would involve lower flows. If the dam were removed during low flow periods, the sediment scoured from the dam would likely be less, with more sediment deposition occurring between Easley Central and the WSII location. To investigate the impact of lower flows, a constant discharge of 500 cfs was run in the model for 50 days, with model output at 10 day and 50 day increments. Figures 15 and 16 present the sediment flux along the channel, with Figures 17 and 18 depicting the change in bed elevation. Table 2 tabulates the sediment mass entering the reservoir, scoured from the reservoir, and scour and deposition along the channel. Approximately 84,475 tons (67,242 cubic yards) of sediment scour from the reservoir over the 50 day interval. A total of 100,848 tons (scour plus incoming load) is passed below the dam, with 19,965 tons depositing in the channel between Easley Central and the WSII location. Thus 20 percent of the total load passed downstream of the dam will deposit between Easley Central and WSII, with 80 percent passing to the lower reaches of Twelve Mile Creek below Lay Bridge. As with the previous simulation, the bulk of the sediment deposition occurs about 1000 – 1500 feet below Lay Bridge. Because of the relatively low flow rate, and low sediment transport capacity, the coarse sands that transported out of the dam will tend to rapidly fall out of suspension when they encounter the quiescent flow conditions of the Lake Hartwell backwater below Lay Bridge.

DISCUSSION

The removal of Easley Central dam will impact both the downstream channel and upstream reservoir morphology. Model results indicate that the maximum scour potential for sediments behind Easley Central dam is approximately 80,000 cubic yards. This includes the maximum scouring effects of a five day duration 3000 cfs two year return flood. The impact to the downstream channel is minimal with only two percent of the total sediment remaining in the downstream channel between Easley Central and WSII, with the bulk of the sediment depositing below Lay Bridge. However, if the dam is removed at relatively low flows (500 cfs), the short term scour and transport will be somewhat less (67,000 cubic yards), with approximately twenty percent of the sediment depositing in the channel between Easley Central and Lay Bridge. These deposits are temporary and will scour during future storm events.

The long term impact to the channel will be minimal, however, in the short term the channel will be impacted, particularly if removal activities occur during low flows. Pools that have formed after removal of WSI and WSII will likely fill, with potential deposition depths of 2 to 3 feet in some areas.

The 2D model results indicate that after the dam is removed, the scour will proceed upstream along the remnant channel thalweg in the reservoir. This path is along the right descending bank line (Western edge of the reservoir) on the outside of a bend in the channel. The Eastern floodplains which have PCB contamination concerns are located on the inside of the bend. This location is generally considered a depositional area in streams (Figure 19). Flow velocities will be higher against the Western bank line opposite of the Eastern flood plains, with scour depths ranging from approximately 10 feet near the dam to 7 feet in the upstream reservoir reaches.

In theory, unconsolidated sand banks will be stable at angles of thirty degrees or greater from the vertical. Considering a vertical sand bank at the maximum scour depth of 10 feet, a 30 degree bank slope will result in a bank set back of approximately 6 feet. Based on sand bank stability, it can therefore be inferred that the maximum bank setback distance (back erosion) would be 6 feet for the Southeastern floodplain area. However, this floodplain area is heavily vegetated with trees and low lying vegetation. Soil borings indicate the existence of fine sediments as well as sands. Thus the Southeastern floodplain stream bank may offer substantial resistance to erosion and failure after the new channel has formed through the reservoir.

Based on the model analysis, the location of the channel that forms through the reservoir reach after the dam is removed will be along the Western edge of the stream. The conceptual alternative for partial dam removal presented by Kestrel Horizons presents a reasonable dam removal concept which will maintain channel alignment away from the Southeastern floodplains and thus further reduce bank erosion risks (Figure 20).

CONCLUSIONS

Model results indicate a maximum scour potential of 80,000 cubic yards of sediment from Easley Central reservoir after the dam is removed, with minimal deposition occurring in the channel between Easley Central and WSII. This prediction is based on channel forming flows occurring in Twelve Mile Creek (3000 cfs or greater) during or after the removal process. Removal of the dam during low flows will potentially result in more deposition in the channel below Easley Central, with less overall scour in the reservoir. All the model simulations indicate that the long-term fate of sediments is the Twelve Mile Creek channel below Lay Bridge. Short term sediment deposition from low flow removal scenarios could result in 2 – 3 feet of sediment occurring in channel reaches between Easley Central and WSII.

REFERENCES

Kestrel Horizons, LLC, "Feasibility Investigation Report Twelve Mile River – ECWD Reach Dam Removal and River Restoration Project, Cateechee, South Carolina", Prepared for South Carolina Department of Natural Resources, May 27, 2011.

Tables and Figures

Table 1. Fate of sediment in Twelve Mile Creek for staged removal scenarios. Data are in dry tons, with deposited sediment having a negative value. Multiply tons by 0.796 to obtain cubic yards

Creek Reach	Dam EL 784 ft	Dam EL 780 ft	Dam EL 776 ft	Dam EL 772 ft	Dam EL 768 ft	Total
Sediment into EC	40735	41858	44044	42762	42452	211851
Sediment out of EC	0	36766	39496	20403	38983	100558
EC to WSI	-140	-8917	-2240	8203	2519	-575
WS1 – WSII	-1124	-10944	1401	-801	6829	-4639
WSII – Lay Bridge	3063	-225	-19598	12871	9103	5214
Below Lay Bridge	42534	58538	63103	83438	64796	312409

Table 2. Fate of sediment in Twelve Mile Creek for 500 cfs simulations. Data are in dry tons, with deposited sediment having a negative value. Multiply tons by 0.796 to obtain cubic yards.

Creek Reach	500 cfs 10 day	500 cfs 50 day
Sediment into EC	1985	16373
Sediment out of EC	24963	84475
EC to WSI	-3862	-3285
WS1 – WSII	-8669	-7345
WSII – Lay Bridge	1219	-9335
Below Lay Bridge	15636	80883

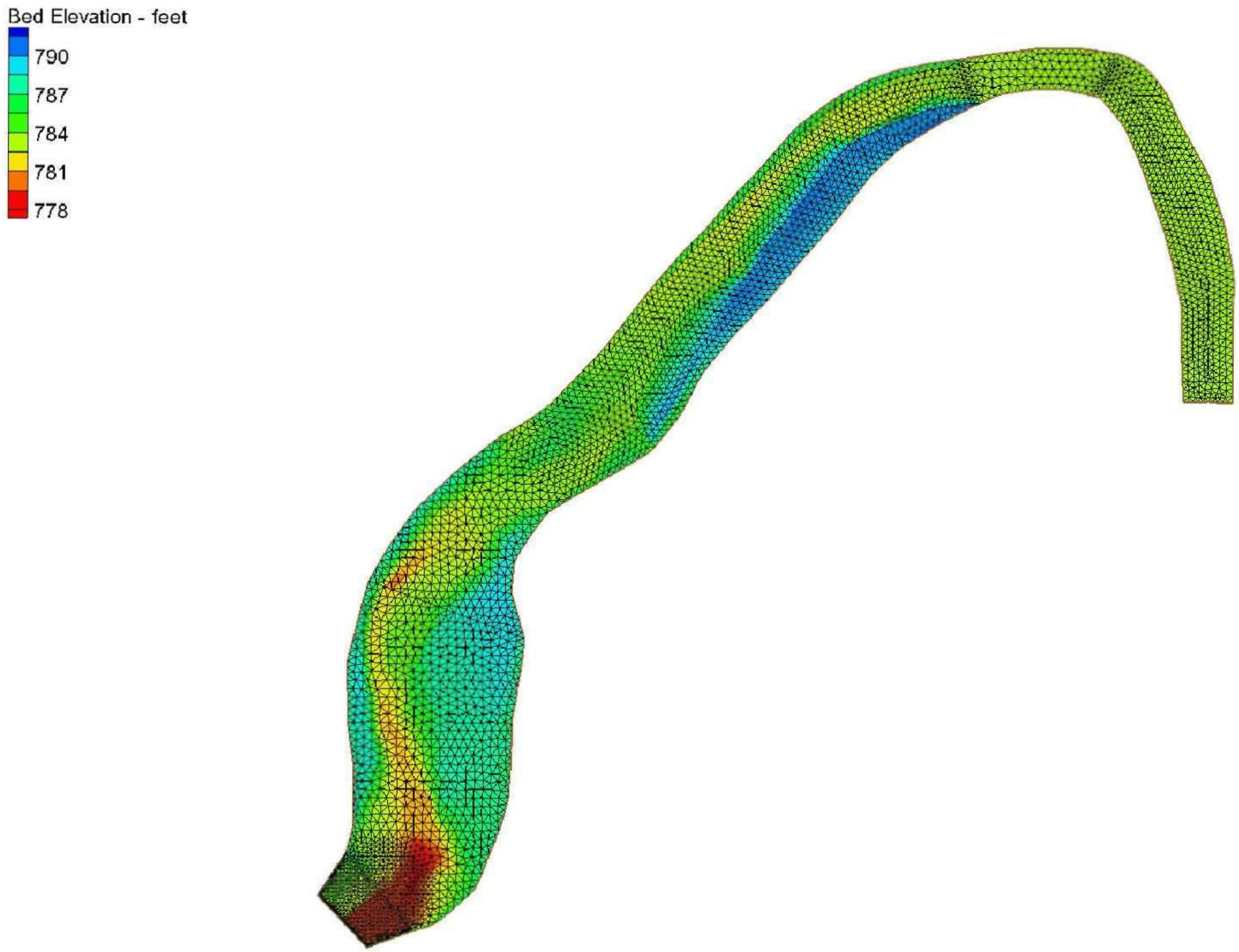


Figure 1. Two dimensional numerical mesh of Easley Central reservoir

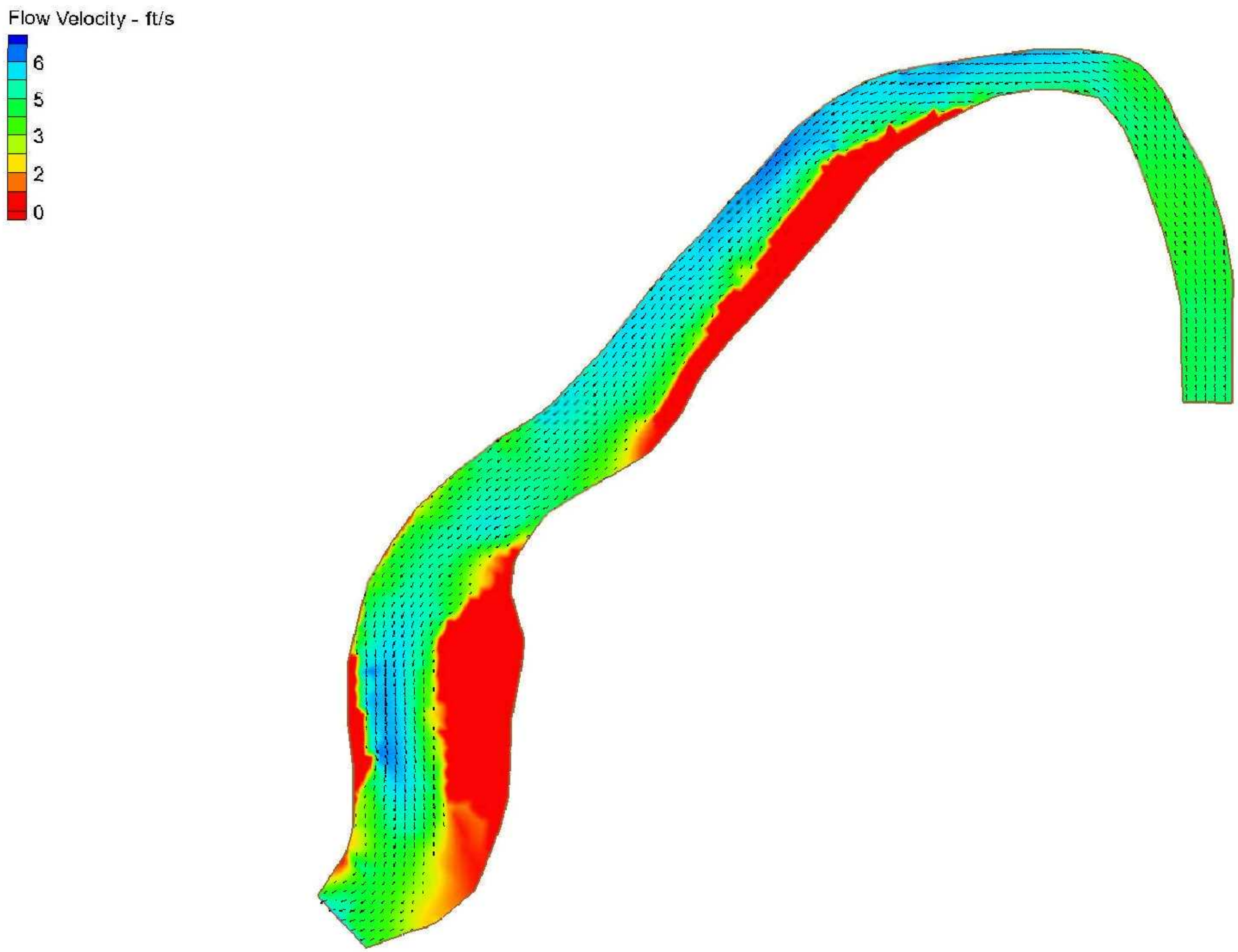


Figure 2. Flow velocity contours and vectors for 3000 cfs flow before dam removal (dam at 784 ft elevation)

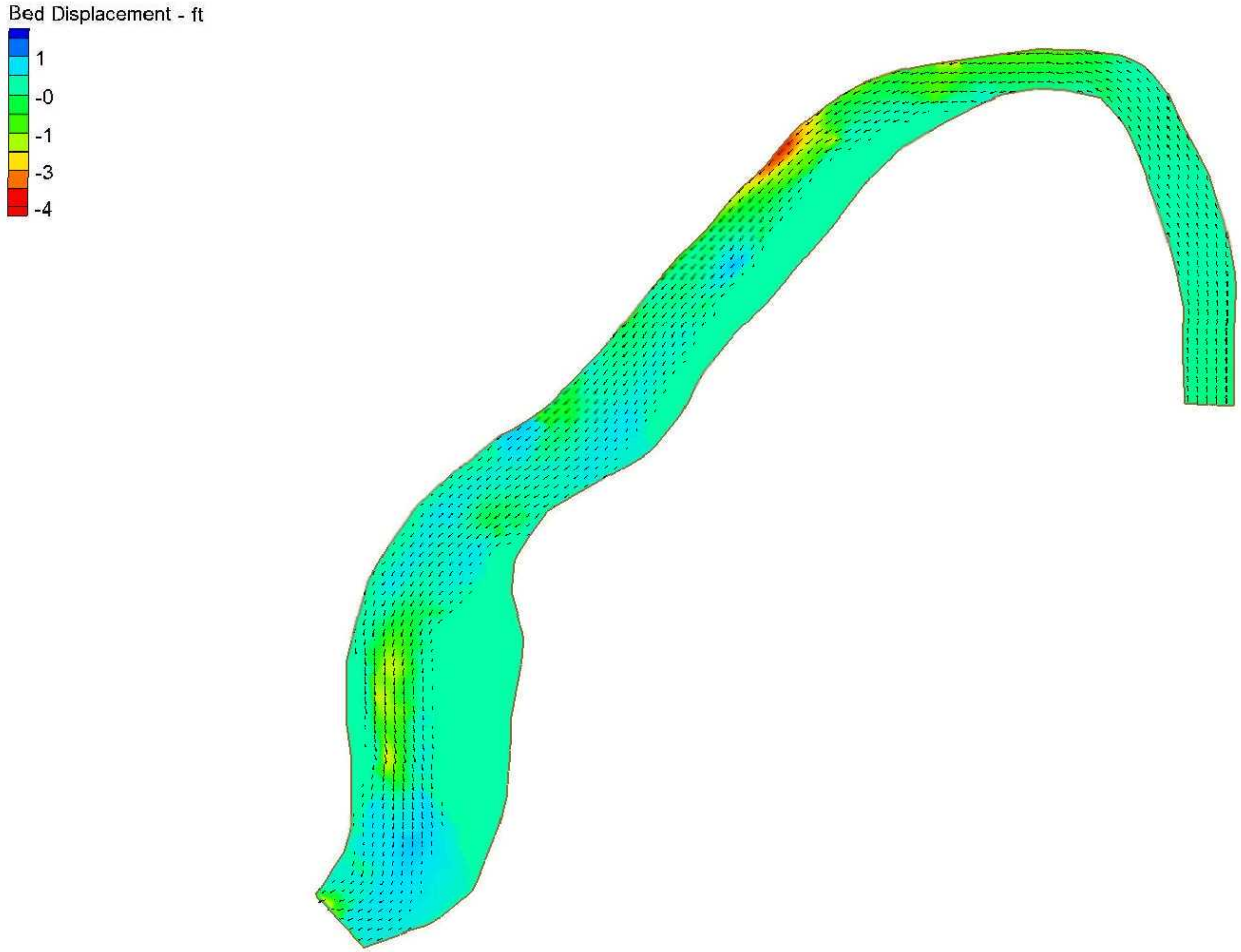


Figure 3. Bed displacement for 3000 cfs flow before dam removal (dam at 784 ft elevation)

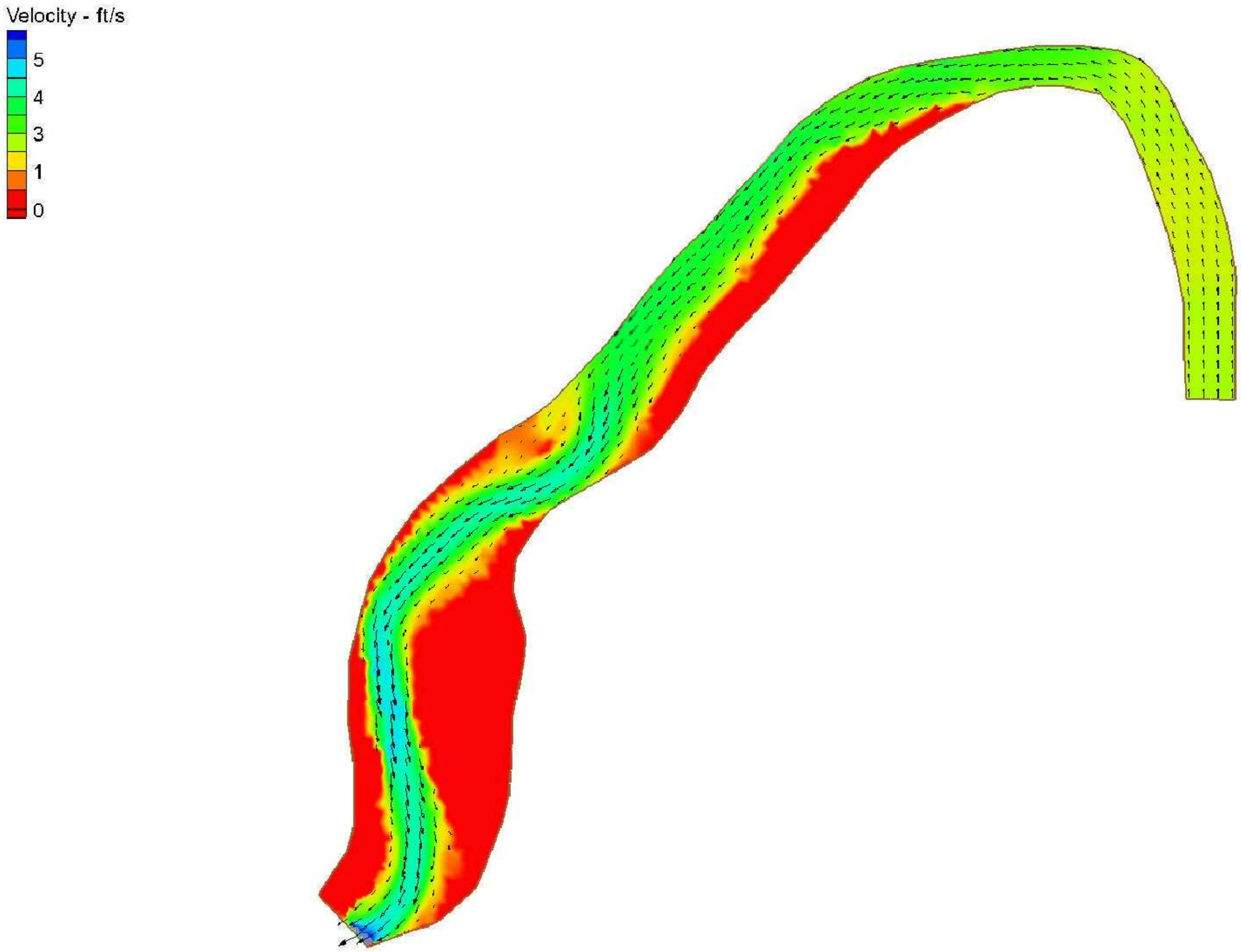


Figure 4. Flow velocity contours and vectors for 1000 cfs after the dam was lowered to 772 ft elevation (lowered 12 feet)

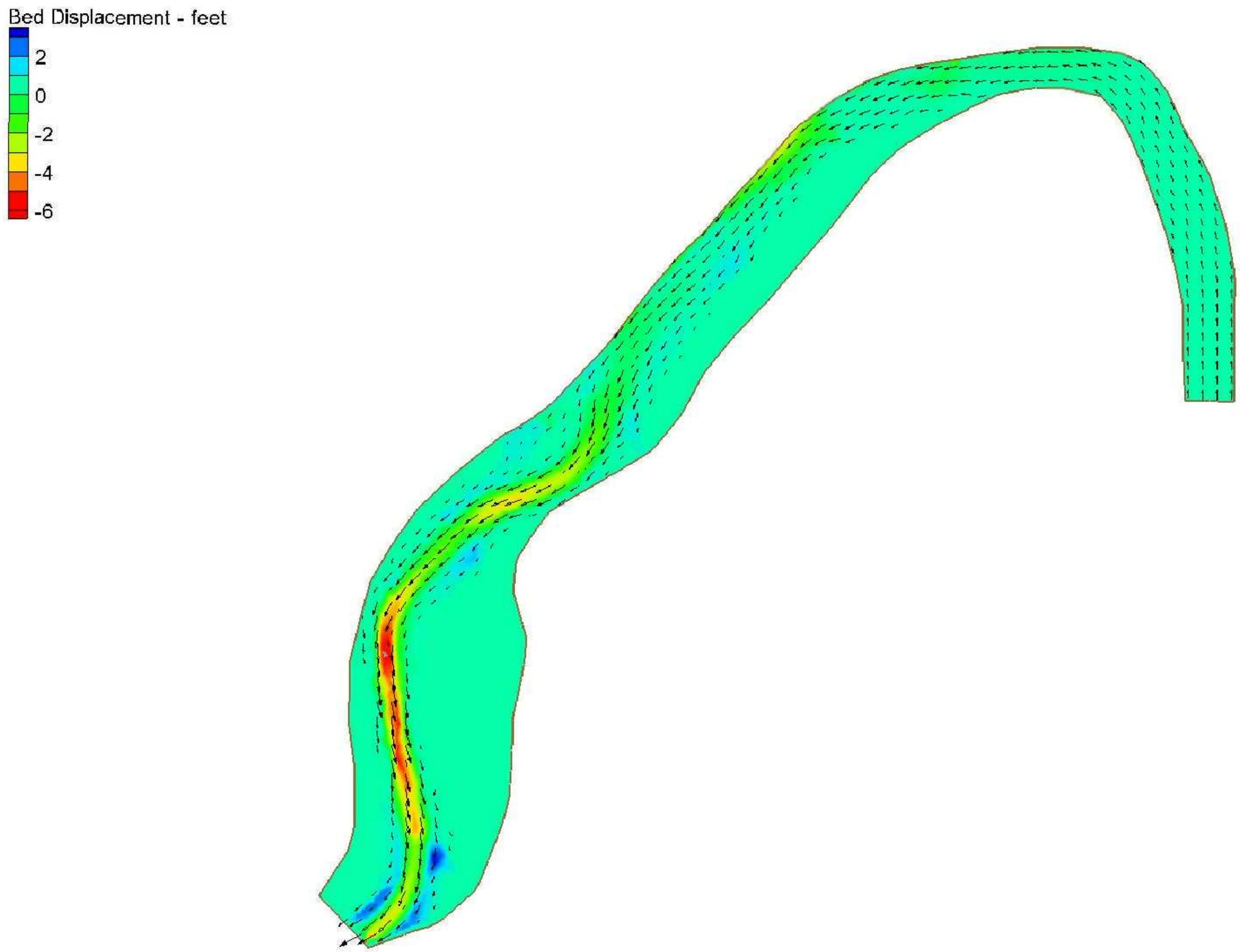


Figure 5. Bed displacement for 1000 cfs flow after the dam was lowered to 772 ft elevation (lowered 12 feet)

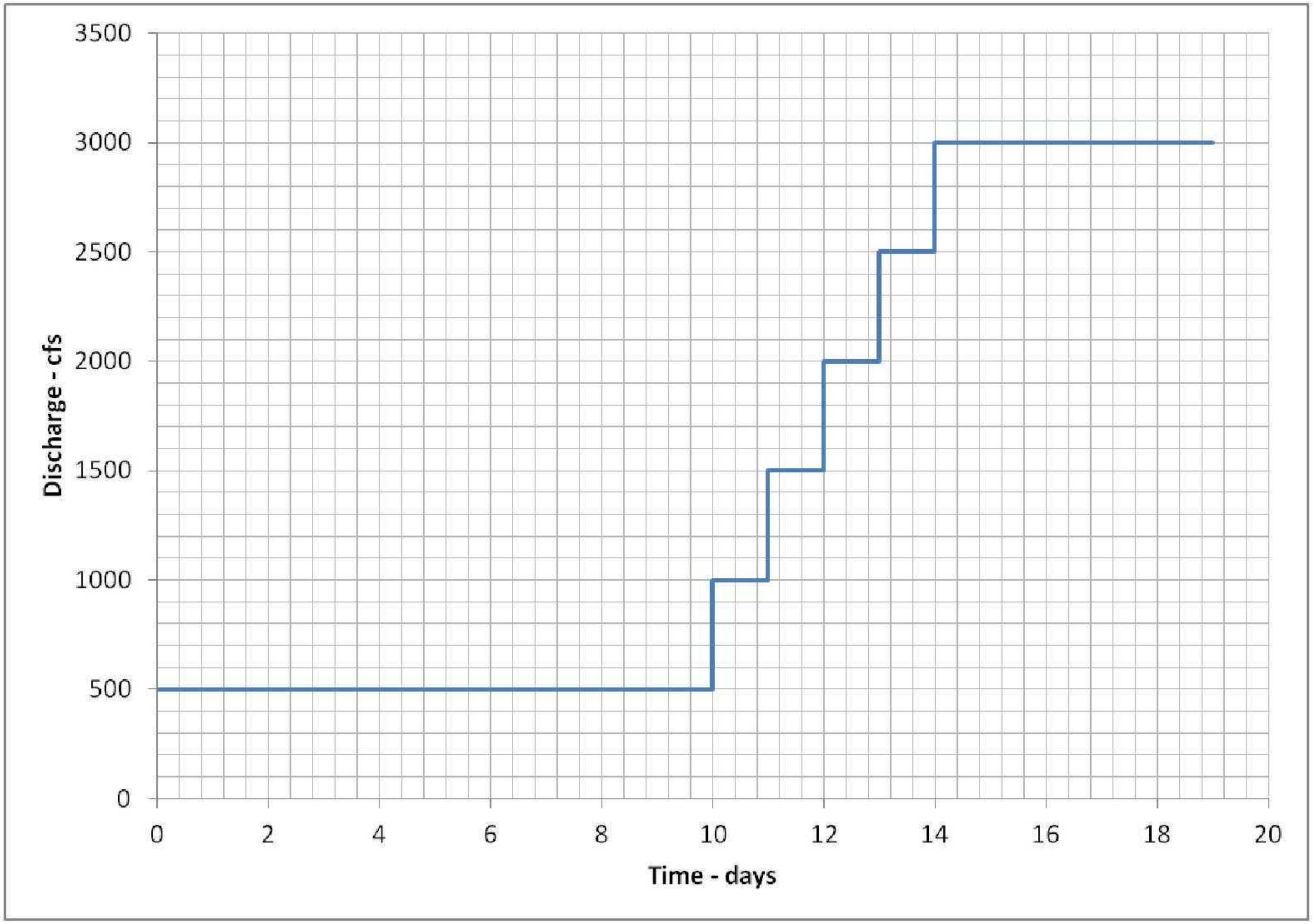


Figure 6. Discharge record simulated for each stage of dam removal

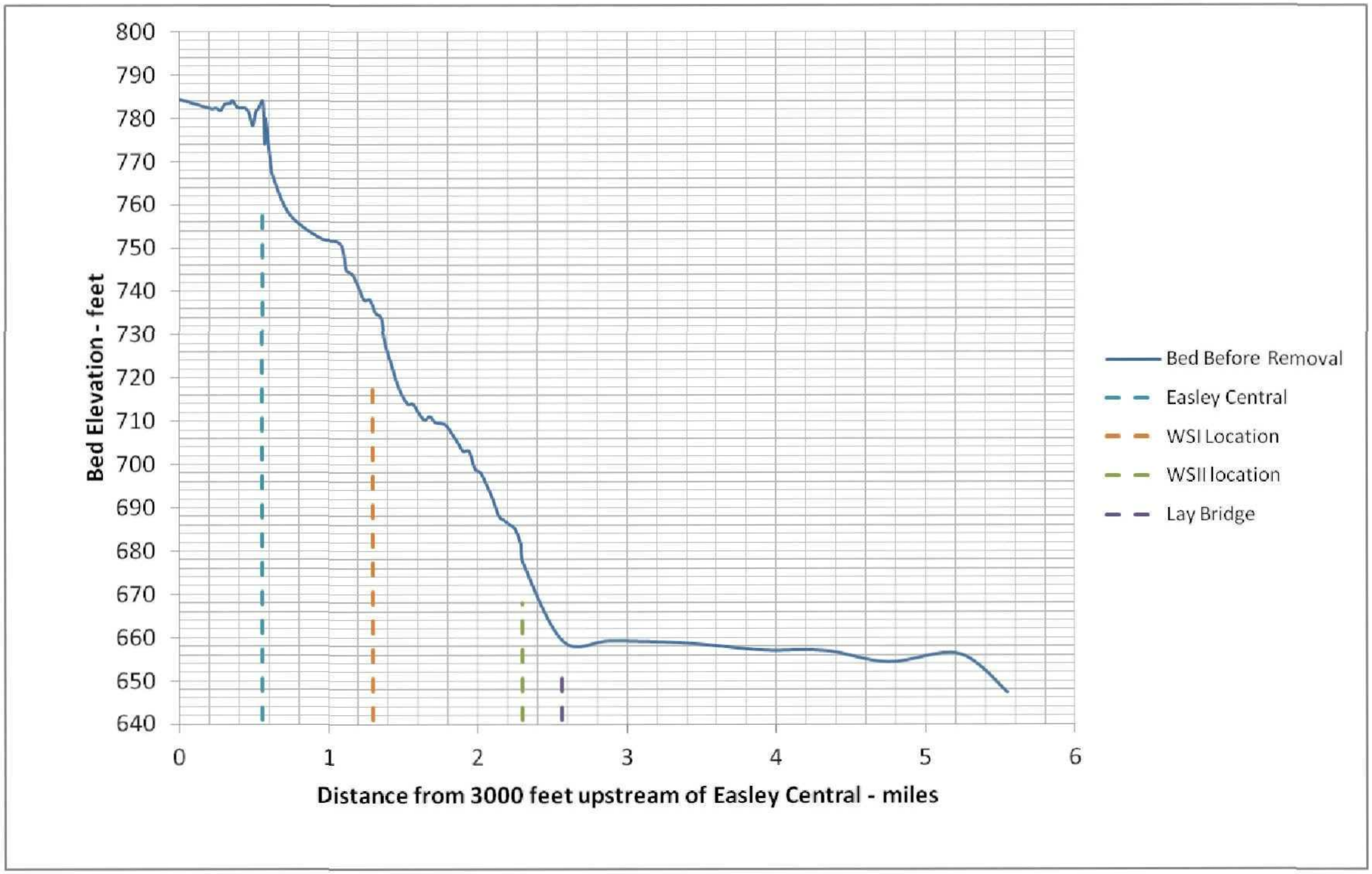


Figure 7. Twelve Mile Creek bed elevation as referenced from 3000 feet above Easley Central reservoir

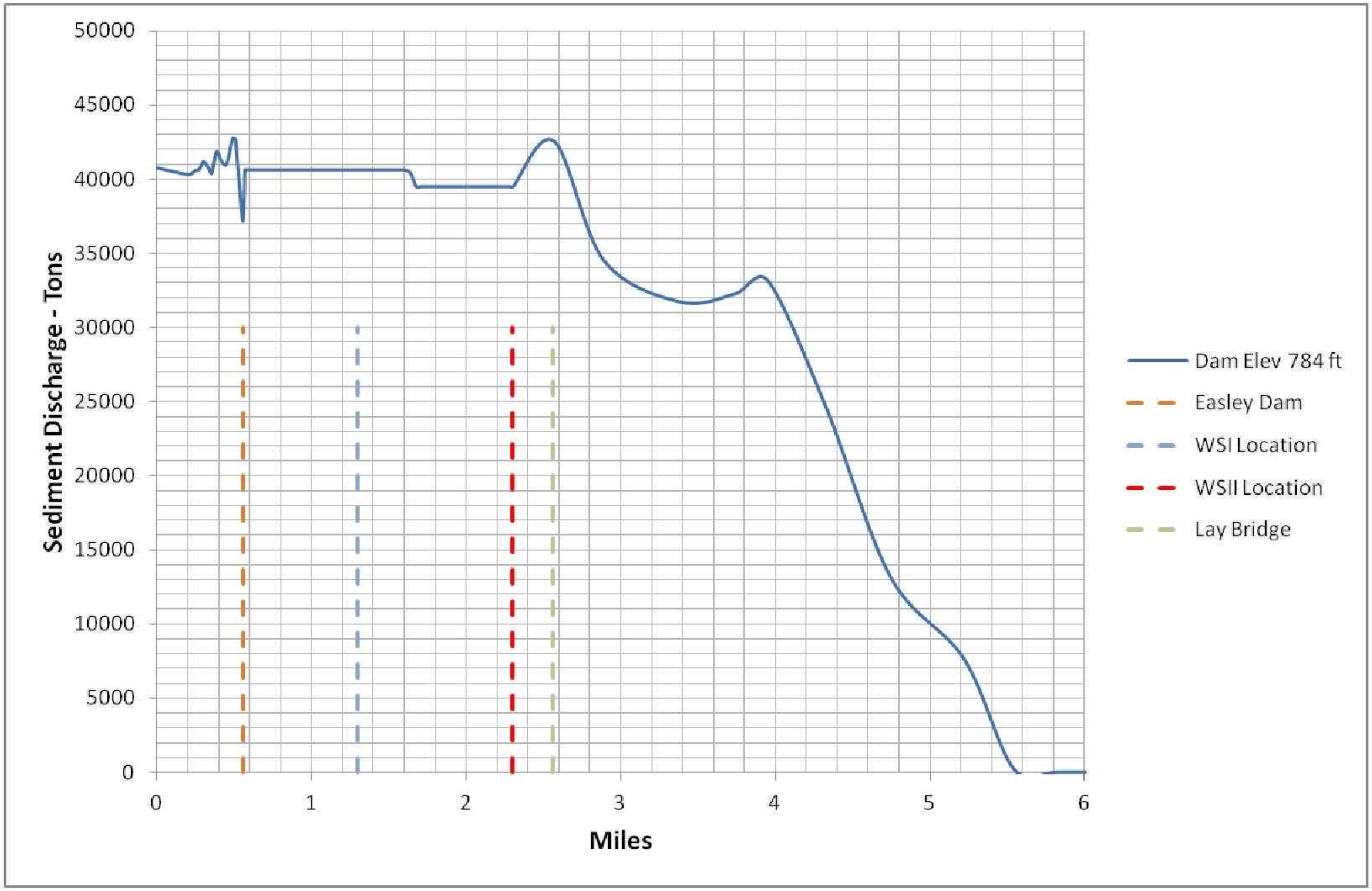


Figure 8. Total sediment discharge along Twelve Mile Creek at dam elevation of 784 feet

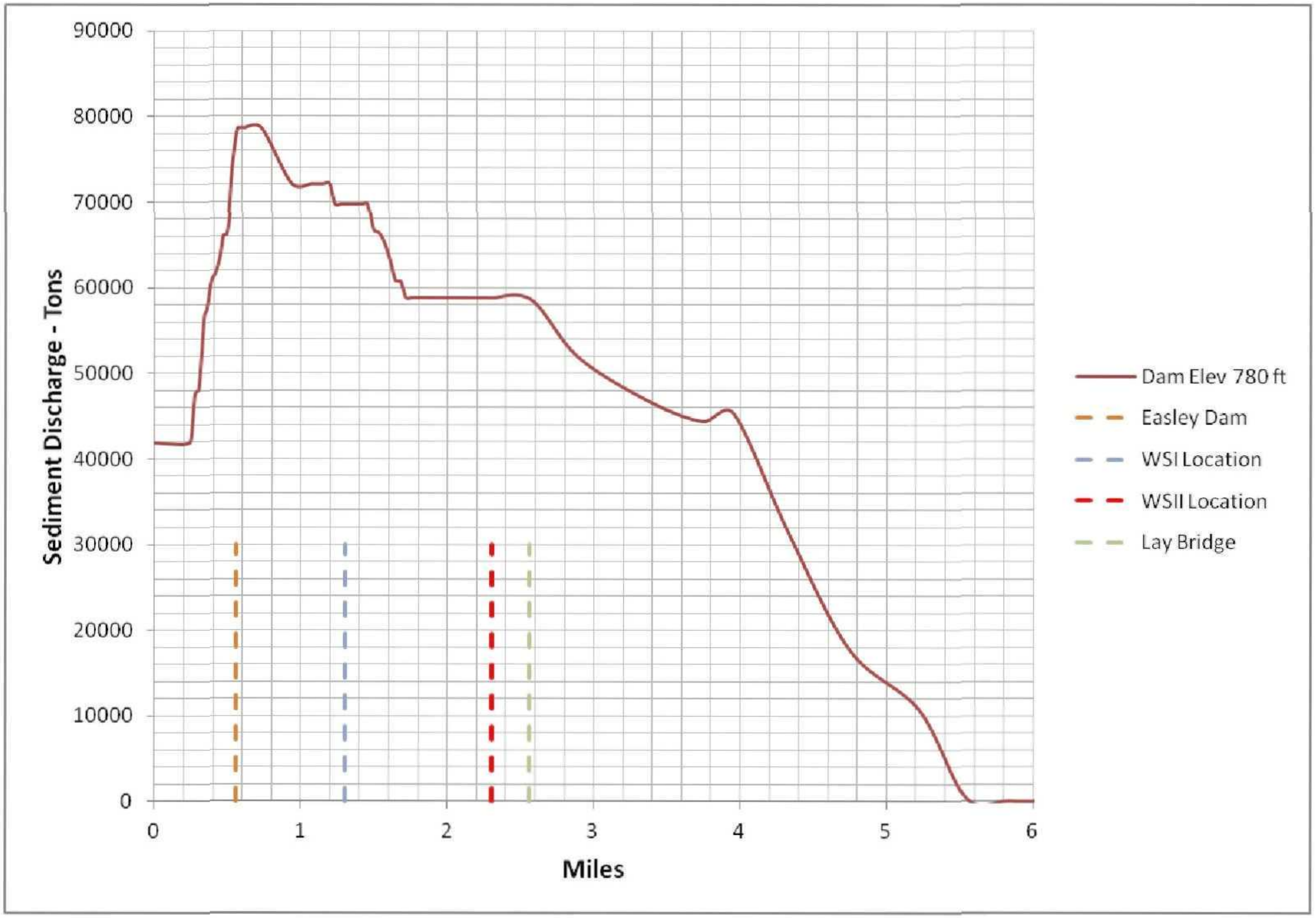


Figure 9. Total sediment discharge along Twelve Mile Creek at dam elevation of 780 feet

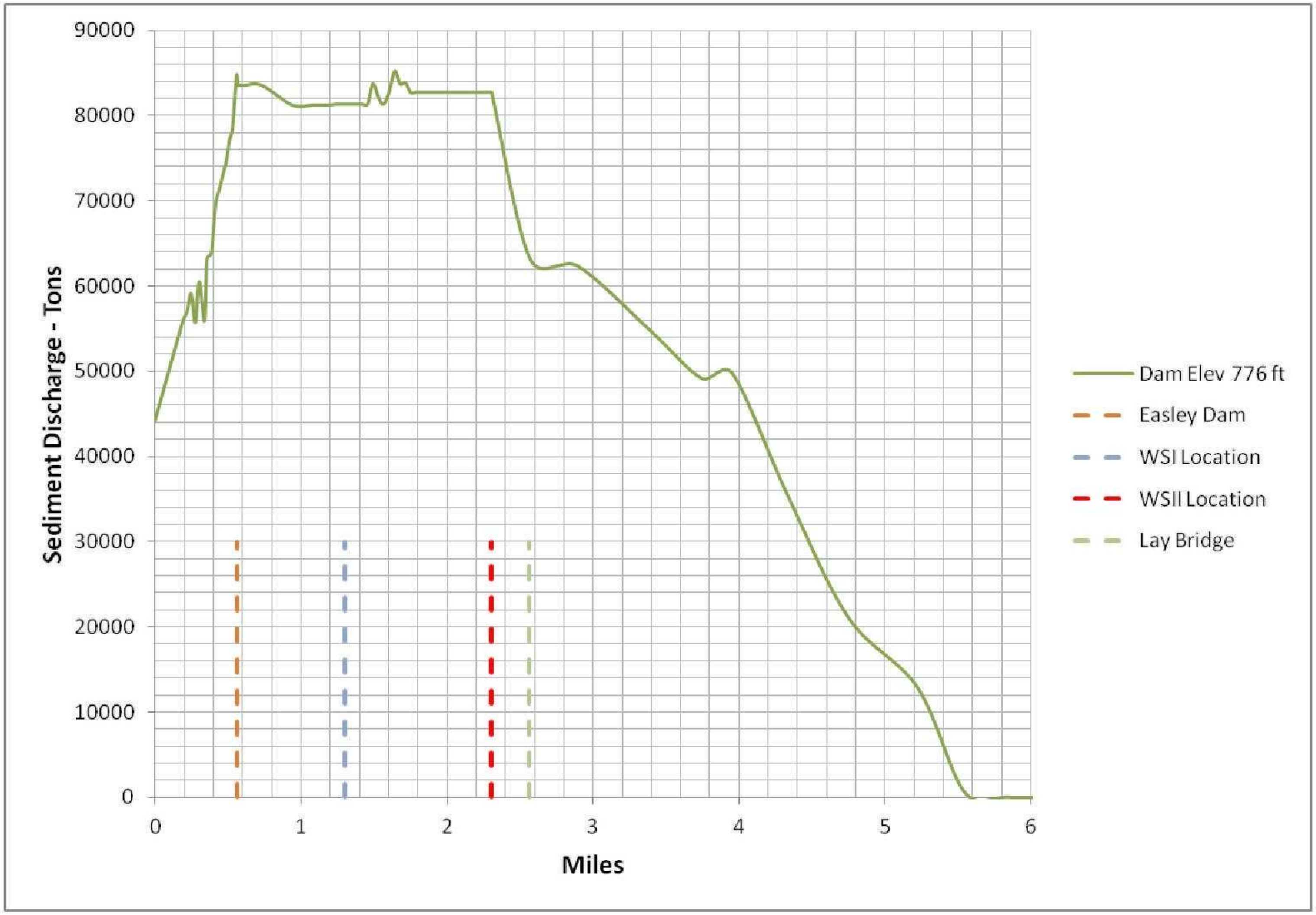


Figure 10. Total sediment discharge along Twelve Mile Creek at dam elevation of 776 feet

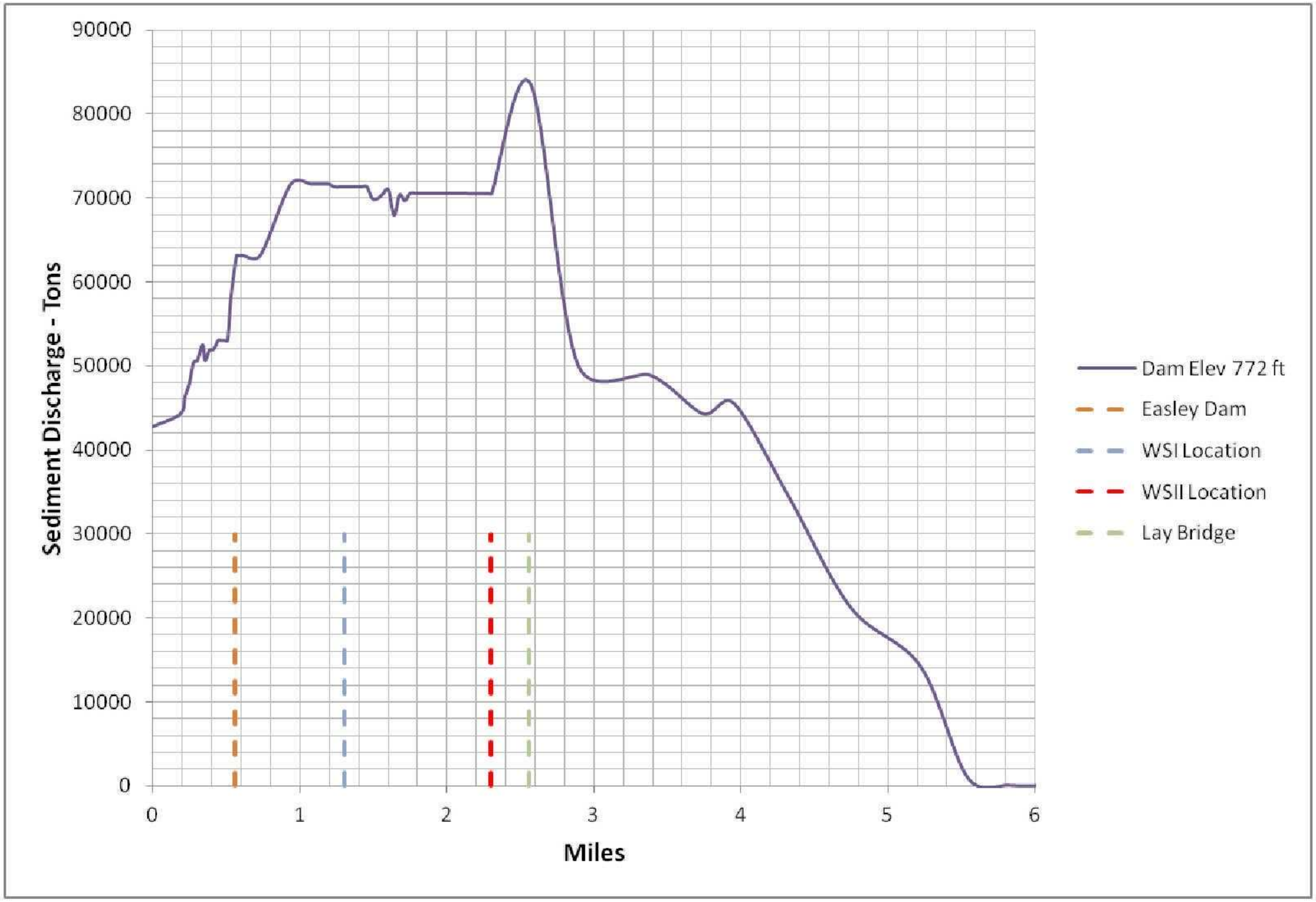


Figure 11. Total sediment discharge along Twelve Mile Creek at dam elevation of 772 feet

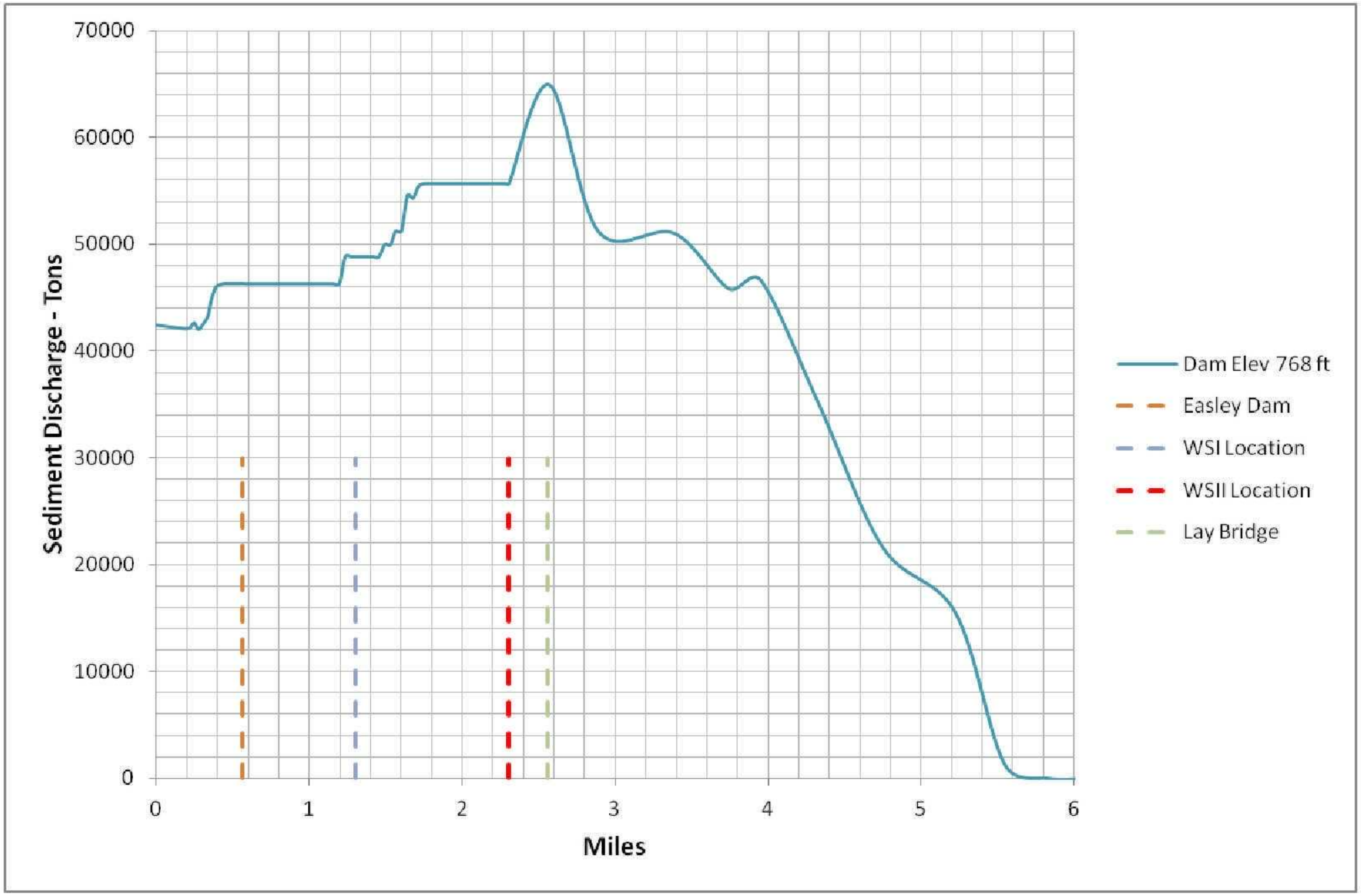


Figure 12. Total sediment discharge along Twelve Mile Creek at dam elevation of 768 feet

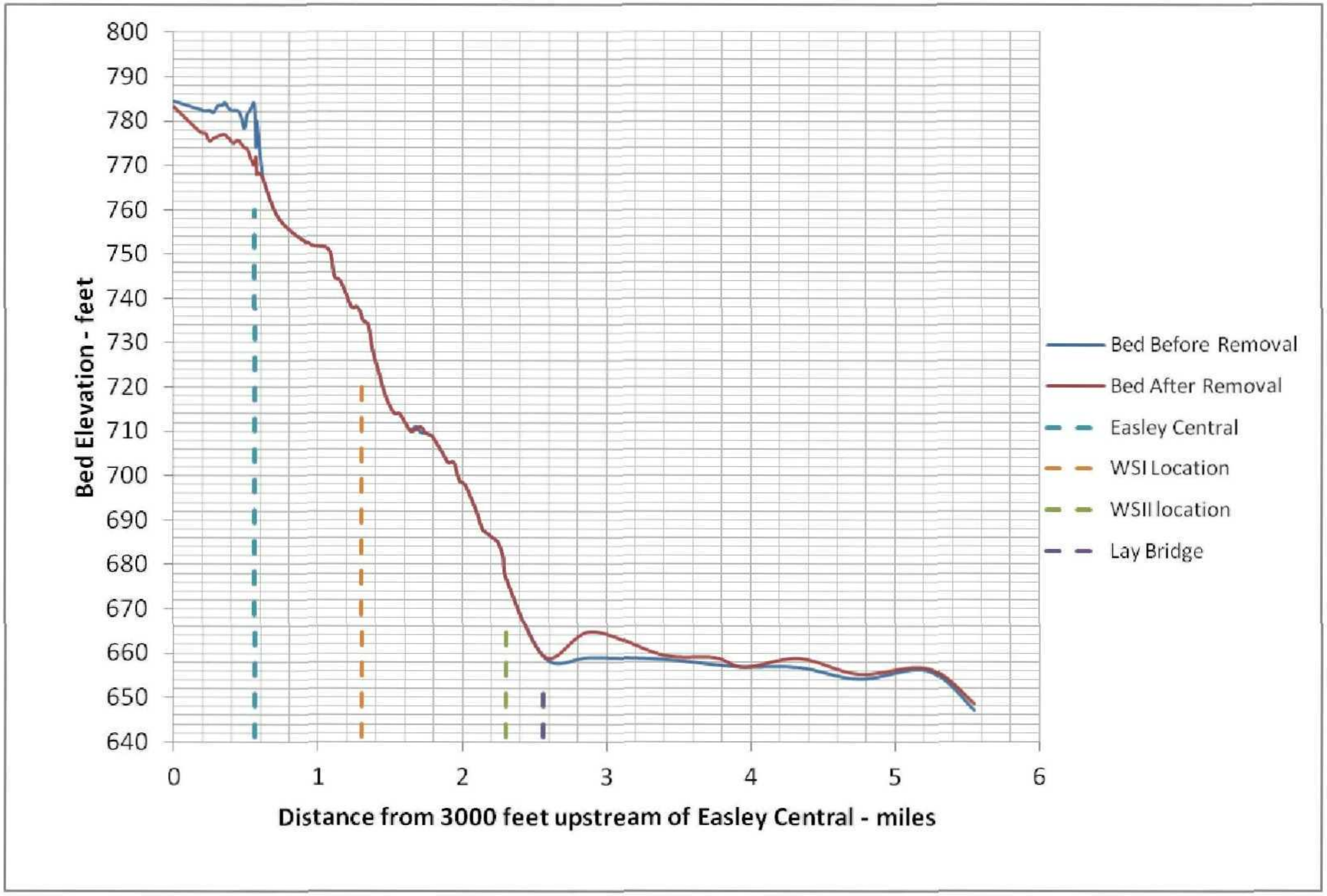


Figure 13. Twelve Mile Creek bed elevation before and after the sequenced dam removal (removal in 4 ft increments)

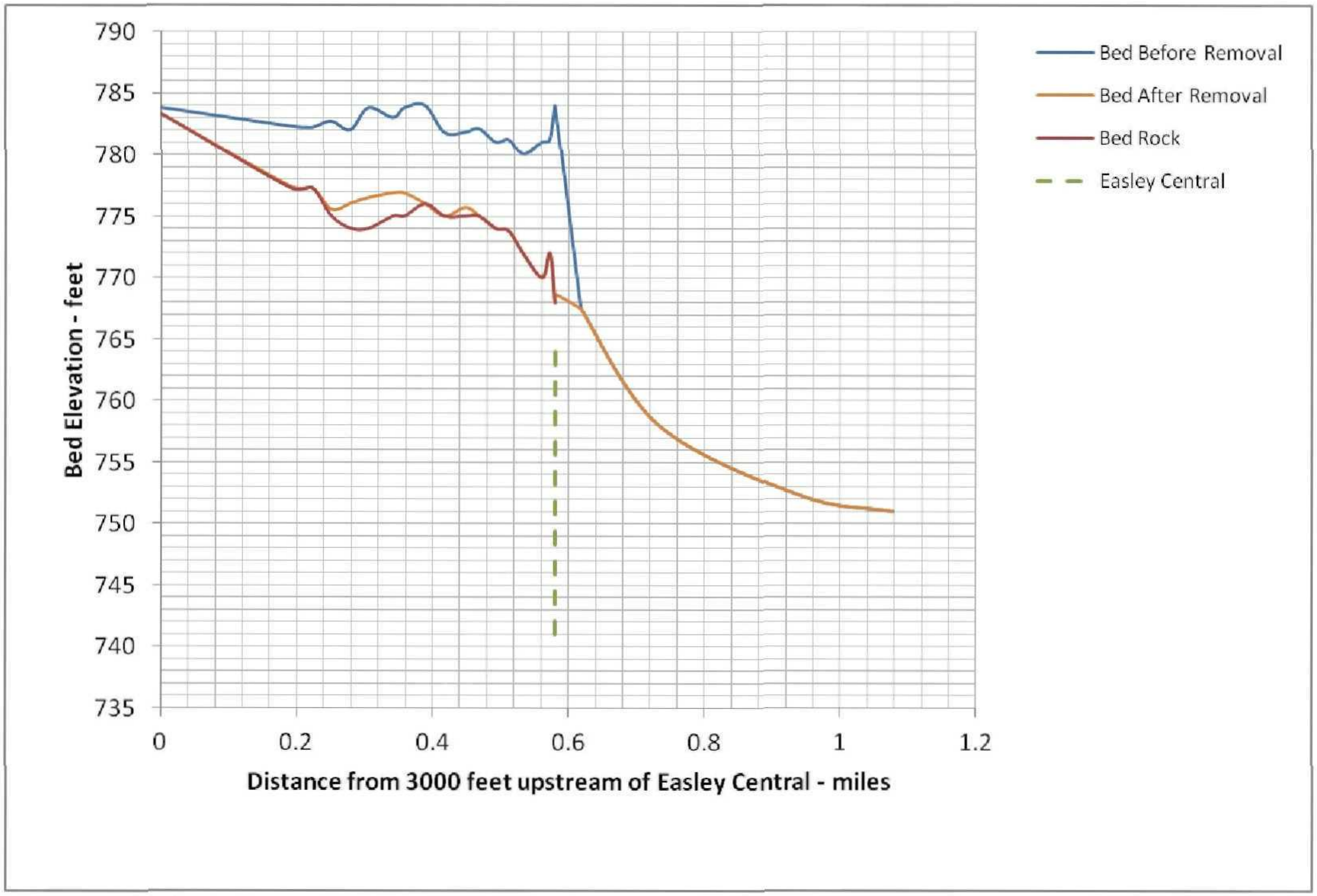


Figure 14. Twelve Mile Creek bed elevation in the vicinity of Easley Central dam before and after dam removal

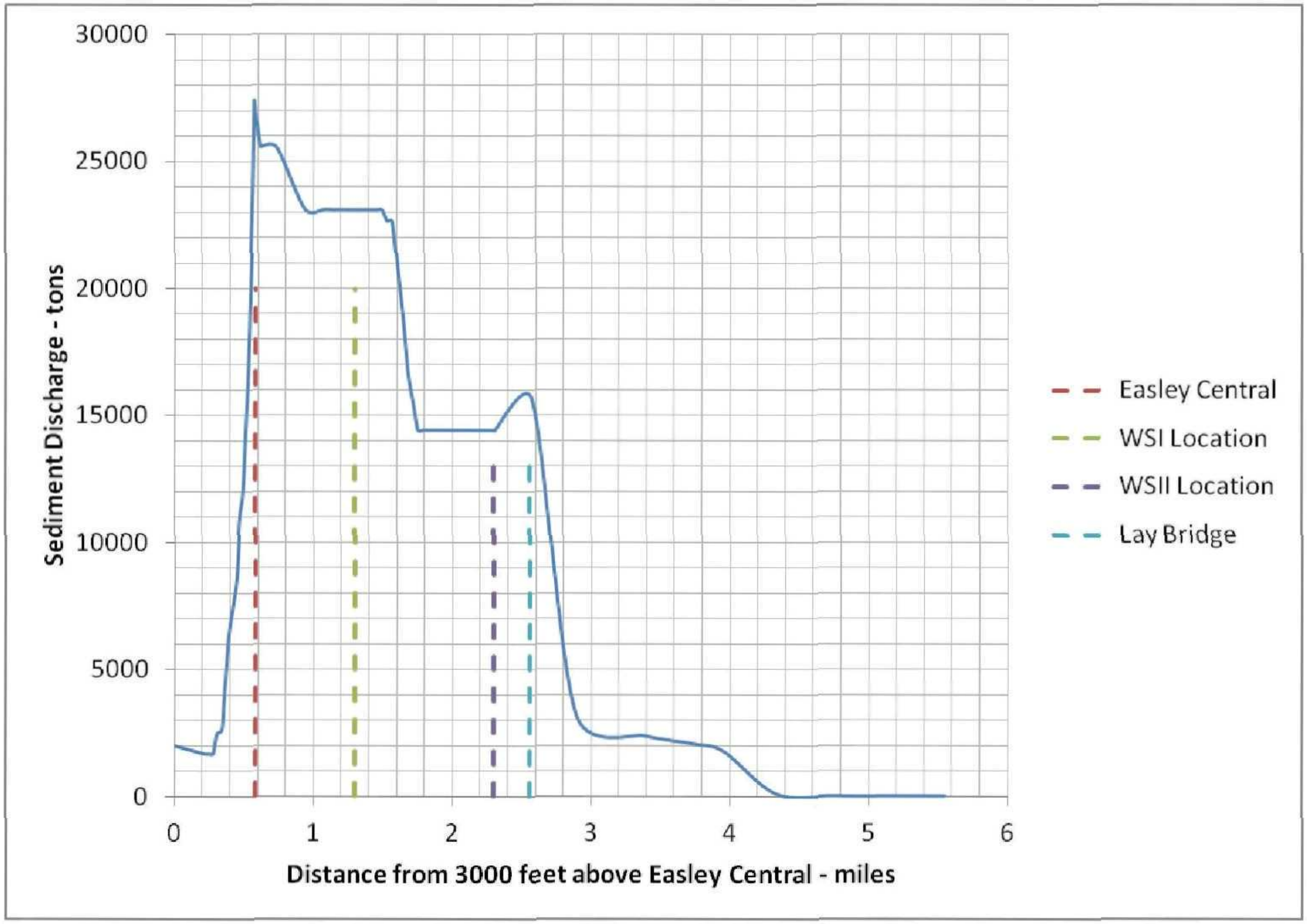


Figure 15. Total sediment discharge along Twelve Mile Creek after 10 days of a continuous 500 cfs flow

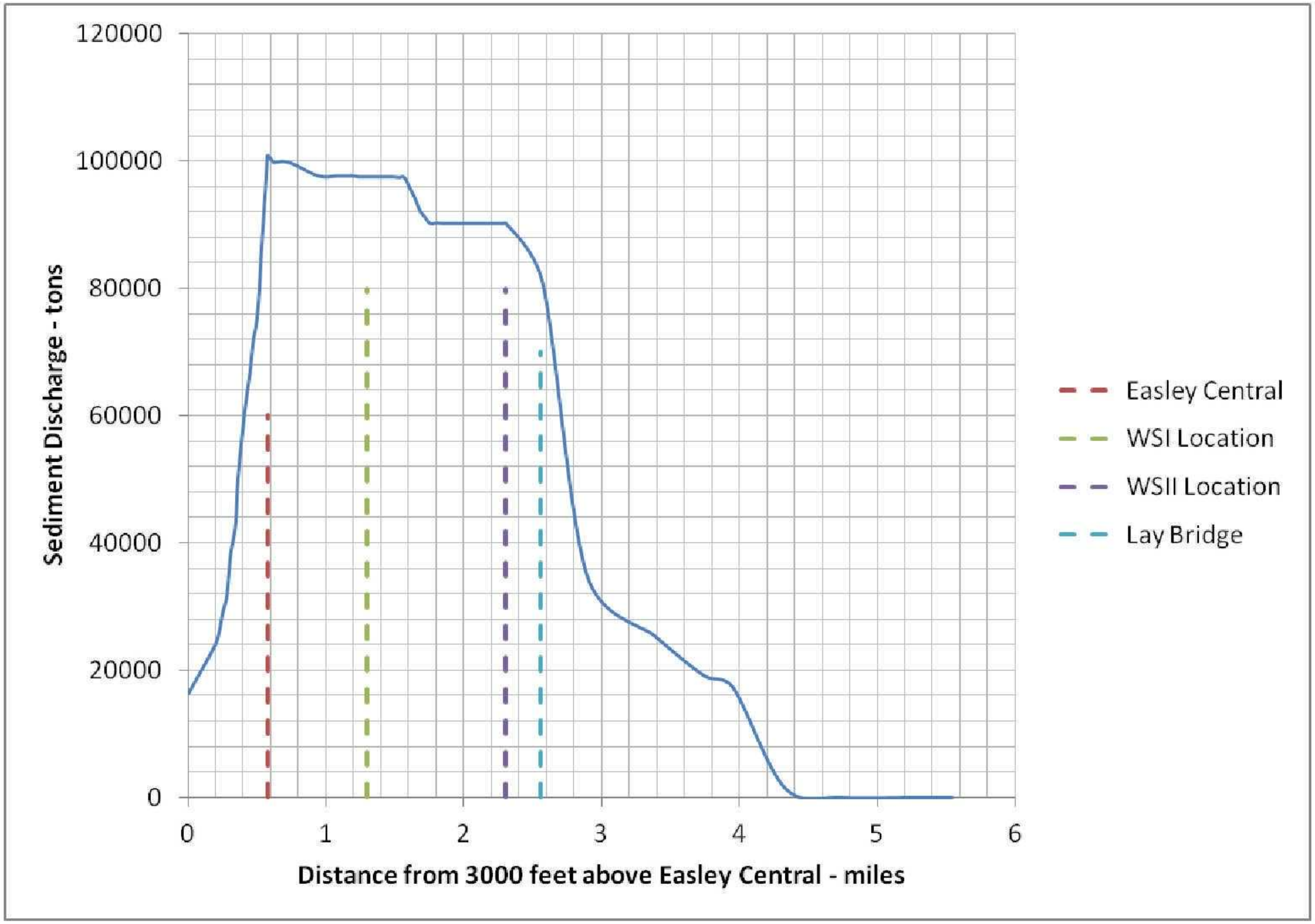


Figure 16. Total sediment discharge along Twelve Mile Creek after 50 days of a continuous 500 cfs flow

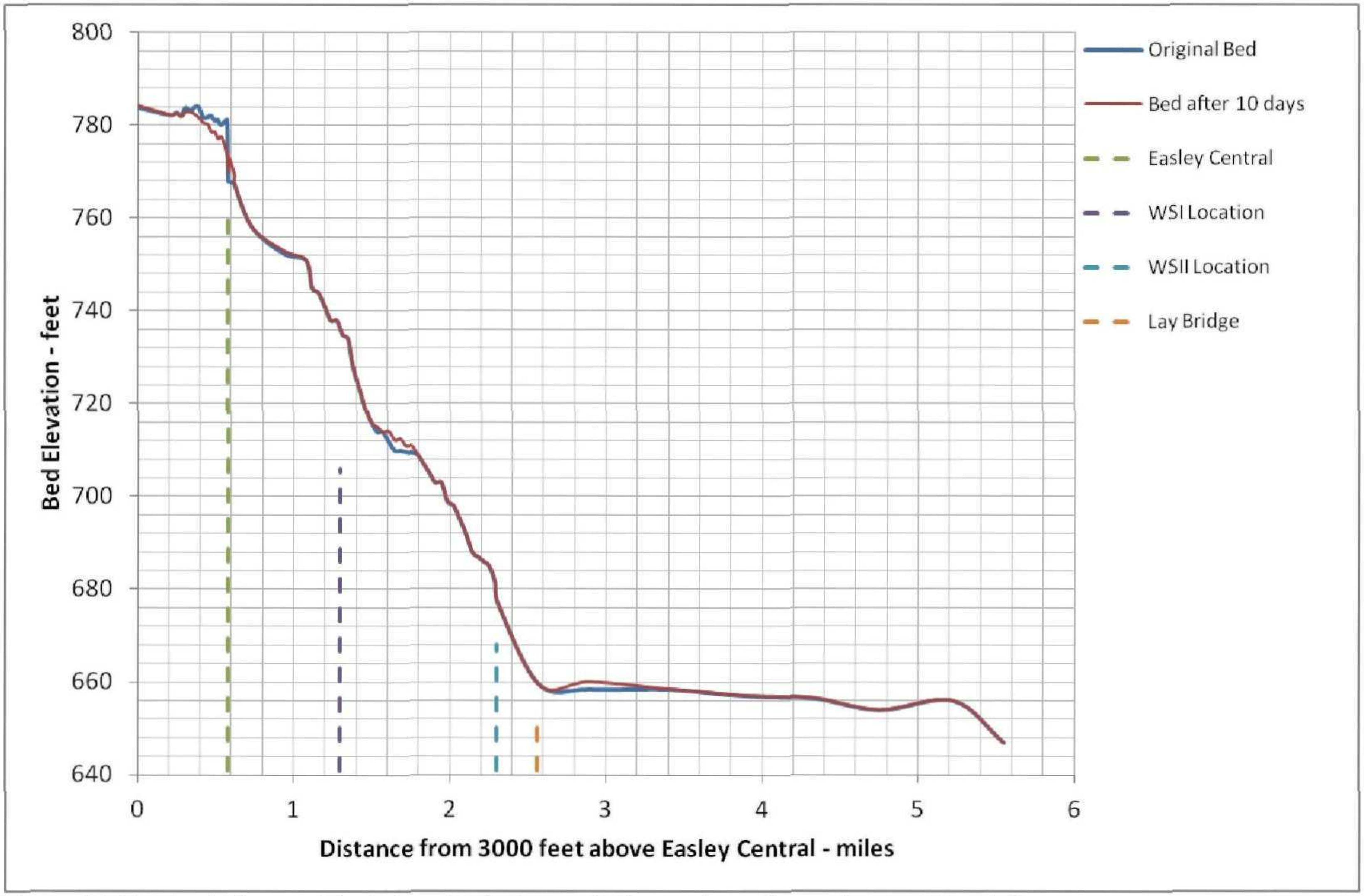


Figure 17. Twelve Mile Creek bed elevation before and after 10 days of a continuous 500 cfs flow

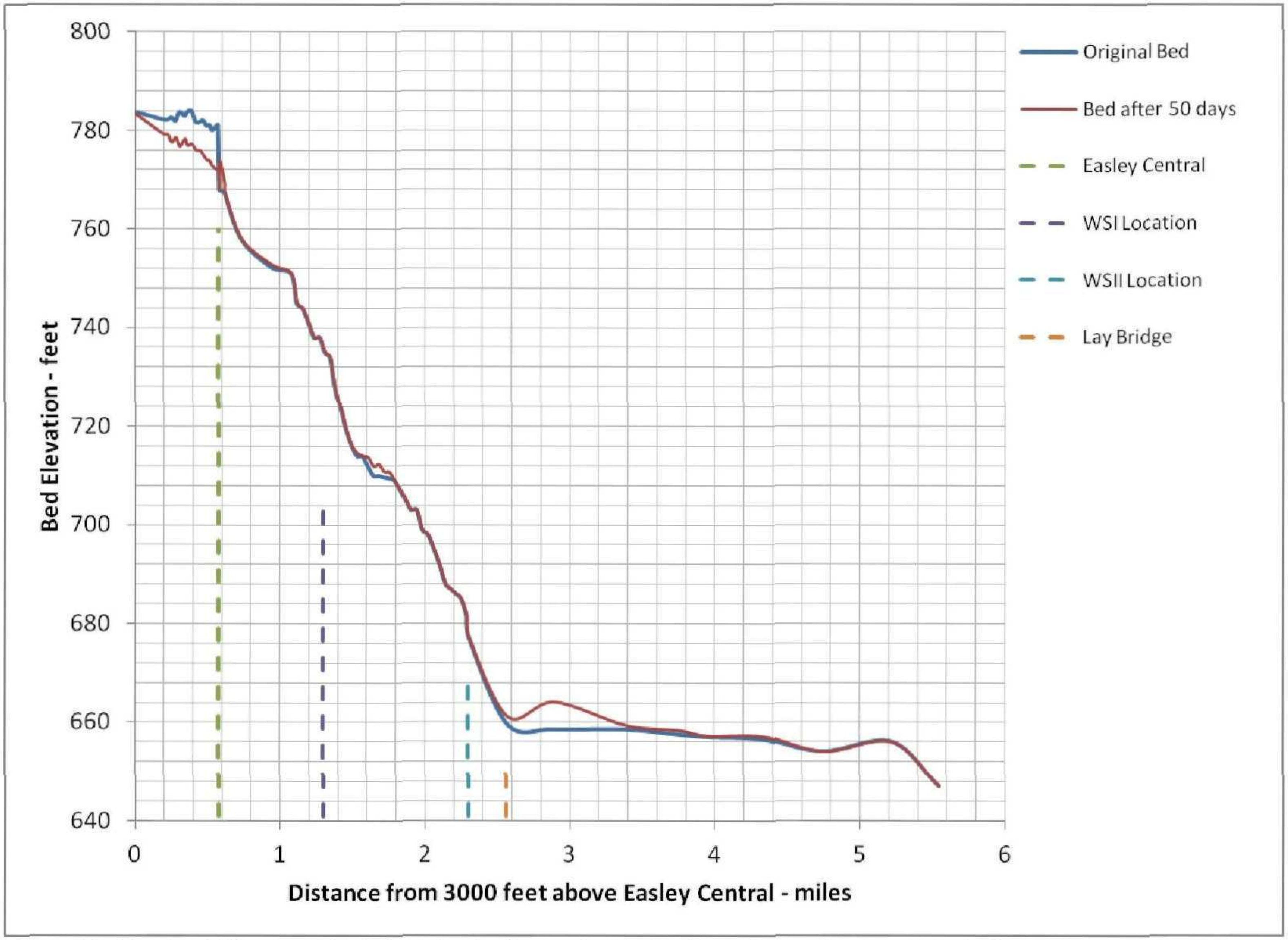


Figure 18. Twelve Mile Creek bed elevation before and after 50 days of a continuous 500 cfs flow

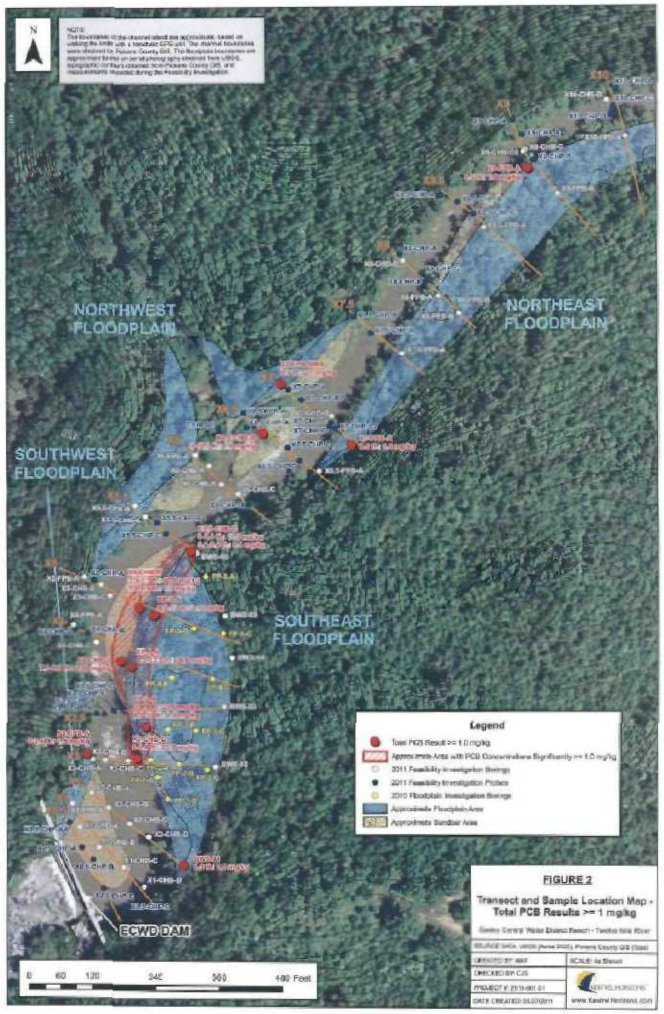


Figure 19. Easley Central reservoir details (Kestrel Horizons 2011)

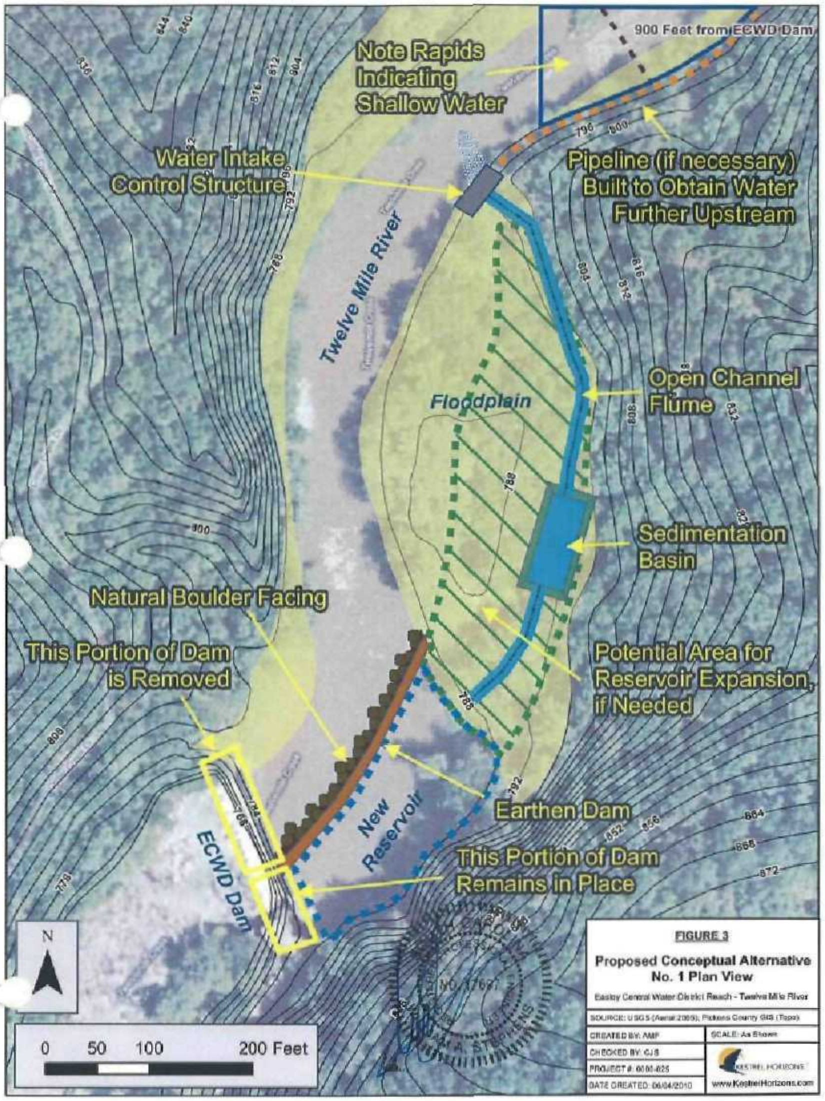


Figure 20. Easley Central reservoir proposed alternative (Kestrel Horizons 2011)